

ห้องสมุดงานวิจัย สำนักงานคณะกรรมการการวิจัยแห่งชาติ



E46223

CHARACTERIZATION OF NANOSTRUCTURED CADMIUM AND ZINC
CHALCOGENIDE SYNTHESIZED BY A MICROWAVE PLASMA
TECHNIQUE FOR DYE-SENSITIZED SOLAR CELLS

WONCHAI PROMNOPAS

DOCTOR OF PHILOSOPHY
IN PHYSICS

THE GRADUATE SCHOOL
CHIANG MAI UNIVERSITY
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20 January 2012

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Chalcogenide Synthesized by a Microwave Plasma
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ABSTRACT

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In this research, p- and n-type intrinsic semiconductor materials CdS, CdTe, ZnTe and ZnO were successfully synthesized by microwave heating and microwave generating of plasma for solid-state reaction. These materials were direct energy band gap which corresponds with visible light then it was important on application in photovoltaic devices.

Hexagonal cadmium sulfide (CdS) crystals were synthesized from 1:1, 1:2, and 1:3 molar ratios of Cd:S powders by a 900 W microwave plasma. The products became pure crystals at 1:2 molar ratio of Cd:S for 120 min and 140 min. The phase,

nanocrystals and its longitudinal optical modes of 1LO and 2LO were detected at 303 and 605 cm^{-1} . Photoemission was determined to be 537 nm (2.31 eV), and direct energy gap to be 2.47 eV for 120 min, and 2.36 eV for 140 min.

Cubic CdTe nanostructures were synthesized from 1:1 molar ratios of Cd:Te by a 900 W microwave plasma for 10, 20 and 30 min. The direct energy gaps were determined to be 1.80 – 1.65 eV which it found that exhibit a pronounced blue-shift as comparable to those of the bulk counterparts.

Cubic ZnTe nanostructures were synthesized from 1:1 molar ratios of Zn:Te by a 600 and 900 W microwave plasma for 30 min. Their green emissions were detected at 563 nm (2.204 eV) using luminescence spectrophotometry.

In addition, the nanocomposited electrolyte of quasi-solid-state ZnO DSSCs with increasing of weight percent of CdTe or ZnTe nanostructure powder which synthesis by microwave plasma technique are correlated with the increase in the V_{oc} , J_{sc} , ff and the solar conversion efficiency (η) of this device. Optimal DSSCs performance was observed at electrolyte 0.10wt% of CdTe-GPE and 0.20wt% of ZnTe-GPE with a maximum photoelectric energy conversion efficiency of 0.093% and 0.318%, respectively.

ชื่อเรื่องวิทยานิพนธ์ การหาลักษณะเฉพาะของแคดเมียมและซิงก์ซาลโคจีไนต์ โครงสร้างนาโนที่สังเคราะห์โดยเทคนิคไมโครเวฟพลาสมา สำหรับเซลล์แสงอาทิตย์ชนิดสีย้อมไวแสง

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บทคัดย่อ

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งานวิจัยนี้ ได้ทำการสังเคราะห์สารกึ่งตัวนำบริสุทธิ์ชนิดพีและชนิดเอ็น (CdS, CdTe, ZnTe และ ZnO) จากปฏิกิริยาของของแข็ง ด้วยเทคนิคไมโครเวฟพลาสมา ซึ่งสารกึ่งตัวนำที่ได้จากการสังเคราะห์เป็นสารที่มีแถบพลังงานชนิดแบบตรงซึ่งมีความกว้างของช่องว่างพลังงานสอดคล้องกับความยาวคลื่นแสง ดังนั้นสารกึ่งตัวนำเหล่านี้จึงมีความสำคัญต่อการประยุกต์ใช้ในอุปกรณ์สำหรับการเปลี่ยนพลังงานแสงให้เป็นพลังงานไฟฟ้า

สารกึ่งตัวนำ CdS ที่มีโครงสร้างแบบ hexagonal ได้ถูกสังเคราะห์ขึ้นด้วยอัตราส่วนของจำนวนโมลระหว่าง Cd:S เป็น 1:1, 1:2 และ 1:3 โดยใช้ไมโครเวฟพลาสมาด้วยกำลังที่ 900 วัตต์ พบว่า ที่อัตราส่วน 1:2 โดยใช้เวลารวมในการให้ความร้อนจากไมโครเวฟพลาสมาเป็น 120 และ 140 นาที ผลึกภัณฑ์ที่ได้มีความบริสุทธิ์สูงได้เฟสแบบโครงสร้างนาโน และเมื่อวิเคราะห์การสั่นด้วยเครื่องรามานสเปกโตรสโคป พบว่า มีโหมดการสั่นตามยาว อันดับที่หนึ่งที่ 303 cm^{-1} และอันดับที่สองที่ 605 cm^{-1} นอกจากนั้นยังได้ตรวจพบการเรืองแสงสูงสุดตรงกับความยาวคลื่น 537 nm (2.31 eV) เมื่อพิจารณาการดูดกลืนแสงพบว่าช่องว่างพลังงานมีค่าเป็น 2.47 eV เมื่อใช้เวลารวมของการเกิดปฏิกิริยาเป็น 120 นาที และ 2.36 eV เมื่อใช้เวลารวมของการเกิดปฏิกิริยาเป็น 140 นาที

โครงสร้างนาโนแบบลูกบาศก์ของ CdTe ถูกสังเคราะห์ขึ้นด้วยอัตราส่วนของจำนวนโมลระหว่าง Cd:Te เป็น 1:1 โดยใช้ไมโครเวฟพลาสมาด้วยกำลังคงที่ 900 วัตต์ ใช้เวลารวมของการเกิดปฏิกิริยาเป็น 10, 20 และ 30 นาที พบว่า สารกึ่งตัวนำมีช่องว่างพลังงานชนิดแบบตรงมีค่าอยู่ระหว่าง 1.80 – 1.65 eV ซึ่งจะมีค่าเป็นลักษณะ blue-shift เมื่อเปรียบเทียบโครงสร้างแบบบัลค์

โครงสร้างนาโนแบบลูกบาศก์ของ ZnTe ถูกสังเคราะห์ด้วยอัตราส่วนของจำนวนโมลระหว่าง Zn:Te เป็น 1:1 โดยใช้ไมโครเวฟพลาสมาด้วยกำลัง 600 และ 900 วัตต์ ใช้เวลารวมของการเกิดปฏิกิริยาเป็น 30 นาที พบว่า ผลึกกันท์ที่ได้ทั้งสองกรณีมีการเรียงแสงมากสุดในช่วงสีเขียวที่ตำแหน่งของความยาวคลื่นเป็น 563 nm (2.204 eV)

นอกจากนั้น สำหรับอิเล็กทรอนิกส์แบบนาโนคอมโพสิตของเซลล์แสงอาทิตย์ชนิดสีข้อมไวแสงที่มี ZnO ทำหน้าที่เป็นโฟโตอิเล็กโตรดนี้ พบว่า การเพิ่มขึ้นของเปอร์เซ็นต์โดยน้ำหนักของผง CdTe หรือ ZnTe ขนาดโครงสร้างนาโนซึ่งสังเคราะห์ด้วยเทคนิคไมโครเวฟพลาสมา ที่นำมาผสมในอิเล็กโตรไลต์แบบเจล มีความสัมพันธ์โดยตรงกับการเพิ่มขึ้นของค่า แรงดันไฟฟ้าของวงจรเปิด (V_{oc}), ความหนาแน่นของกระแสลัดวงจร (J_{sc}), ฟิสิกเตอร์ (ff) และประสิทธิภาพการเปลี่ยนพลังงานแสงอาทิตย์เป็นพลังงานไฟฟ้า (η) ของเซลล์แสงอาทิตย์ชนิดสีข้อมไวแสง โดยเมื่อผสม CdTe ที่ 0.10 เปอร์เซ็นต์โดยน้ำหนักลงในอิเล็กโตรไลต์แบบเจล จะให้ค่าประสิทธิภาพของเซลล์แสงอาทิตย์ชนิดสีข้อมไวแสงสูงสุดที่ 0.093 เปอร์เซ็นต์ และหากผสม ZnTe ที่ 0.20 เปอร์เซ็นต์โดยน้ำหนักลงในอิเล็กโตรไลต์แบบเจล จะให้ค่าประสิทธิภาพของเซลล์แสงอาทิตย์แบบสีข้อมไวแสงสูงสุดที่ 0.318 เปอร์เซ็นต์

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ABBREVIATIONS AND SYMBOLS

Physical constants

Avogadro constant, N_A	=	$6.022 \times 10^{23} \text{ mol}^{-1}$
Boltzmann constant, k	=	$1.3806 \times 10^{-23} \text{ J K}^{-1}$
Elementary charge, e	=	$1.602 \times 10^{-19} \text{ C}$
Electron mass, m_e	=	$9.109 \times 10^{-31} \text{ kg}$
Planck constant, h	=	$6.626 \times 10^{-34} \text{ J s}$
Vacuum permittivity, ϵ_0	=	$8.854 \times 10^{-12} \text{ F m}^{-1}$
Velocity of light, c	=	$2.998 \times 10^8 \text{ m s}^{-1}$
1 electron volt, 1eV	=	$1.602 \times 10^{-19} \text{ J}$

Physical variables

ν	=	Frequency
ω	=	Angular frequency
ω_c	=	Plasma frequency
λ	=	Wavelength
\mathbf{k}	=	Wave vector
m^*	=	Effective mass
m_e^*	=	Electron effective mass
m_h^*	=	Hole effective mass
ff	=	Fill factor
η	=	Energy conversion efficiency

J_{sc}	=	Short circuit current density
V_{oc}	=	Open circuit voltage
P_{in}	=	Incident light power
P_{max}	=	Maximum power output
V_{max}	=	Maximum photovoltage
E_g	=	Energy band gap
E_F	=	Fermi energy
$g_c(E)$	=	Density of states in the conduction band
$g_v(E)$	=	Density of states in the valence band
n_0	=	Electron concentrations
p_0	=	Hole concentrations
N_C	=	Conduction-band effective densities of state
N_V	=	Valence-band effective densities of state
n_i	=	Intrinsic carrier concentration
E_i	=	Fermi energy in an intrinsic semiconductor
χ	=	Electron affinity
ϕ	=	Work function
V_{bi}	=	Built-in potential
W_D	=	Depletion width
ϵ'	=	Relative permittivity or dielectric constant
θ_A	=	Mean power transfer per electron
δ	=	Loss angle
E_{rms}	=	Root-mean-square electric field

Abbreviations

A°	=	Angstrom
PL	=	Photoluminescence Spectrometry
SEM	=	Scanning Electron Microscopy
TEM	=	Transmission Electron Microscopy
XRD	=	X-Ray Diffraction Spectrometer
JCPDS	=	The Joint Committee for Powder Diffraction Standards
GPE	=	Gel Polymer Electrolyte
DSSCs	=	Dye sensitized solar cells
HOMO	=	Highest occupied molecular orbital
LUMO	=	Lowest unoccupied molecular orbital
AM	=	Air mass
LHE	=	Light harvesting efficiency